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Effect of Final Felling on Natural Regeneration in *Rhizophora* dominated Forests of Matang Mangrove Reserve

P. B. L. SRIVASTAVA and ABDULLAH SANI bin SHAFFIE[1]
Faculty of Forestry, Universiti Pertanian Malaysia

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RINGKASAN

Satu penyelidikan telah dijalankan untuk menentukan kesan-kesan penebangan akhir ke atas pemulihan semula jadi di kawasan hutan simpanan bakau. Penyelidikan ini dijalankan di atas dua kompatmen (No. 38 dan 39) yang berdampingan (klas innudasi III dan IV) yang mempunyai jenis hutan Rhizophora. *Tiga bidang kawasan yang akan ditebang dan tiga kawasan yang telah ditebang dalam masa enam bulan yang lepas di ambil sebagai sempel penyelidikan ini.*

Empat species dicatitkan sebelum dan selepas penebangan. Species yang paling banyak ialah Rhizophora apiculata *diikuti oleh* Bruguiera parviflora. *Kesemua bidang kawasan mempunyai kepadatan stok yang tinggi terutama sekali dengan anakbenih* Rhizophora.

Perbezaan ternyata untuk kedua-dua species dalam kelas ketinggian di antara bidang kawasan semasa belum dan lepas penebangan. Bilangan maxima anakbenih Rhizophora *sebelum penebangan untuk kelas ketinggian 1'–5' ialah 72 peratus, kurang dari 1' ialah 25 peratus dan 5'–10' ialah 3 peratus. Corak ini sama selepas penebangan melainkan anakbenih dalam kelas 1'–5' yang mana bilangannya berkurangan (54 peratus). Bilangan anakbenih yang kurang dari 1' tinggi ternyata bertambah tetapi di dalam kompatmen 38, kekurangan anakbenih* Rhizophora *selepas penebangan tidak ternyata bertambah. Keadaan ini berlainan untuk kompatmen 39. Bagi species* B. parviflora, *bilangan maxima anakbenih di dalam kumpulan kurang dari 1' ialah 80 peratus sebelum dan selepas penebangan. Di bidang kawasan 6, yang telah ditebang, species ini bertambah sebanyak 16 peratus. Kebanyakan bidang kawasan dalam penyelidikan ini mempunyai kepadatan stok anakbenih* Rhizophora *yang memuaskan.*

SUMMARY

A study was undertaken to determine the effect of final felling on the natural regeneration of mangrove forests in Matang Reserve. Two adjoining compartments (nos. 38 and 39) having typical Rhizophora *forests and belonging to innundation classes III and IV were located from which three plots which were ready for felling and another three which had been felled during the past six months, were sampled.*

Although, four species were recorded both at pre-felling and post-felling stages, the most common were Rhizophora apiculata *and* Bruguiera parviflora. *The former was more abundant than the latter in most of the plots. All the plots were highly stocked particularly with* Rhizophora *seedlings.*

Both the species showed considerable variation in different height classes in between the plots both at prefelling and post-felling stages. Before felling the maximum number of seedlings of Rhizophora *belonged to 1' – 5' height class (72%) those below 1' and between 5' – 10' accounted for 25 per cent and 3 per cent respectively. After felling, the pattern was the same but the proportion of the seedlings in 1' – 5' group decreased to 54 per cent. Those below 1' increased in number. A pronounced deleterious effect was not observed on the stocking of* Rhizophora *seedlings in compartment 38 after logging. The reverse was true in the overcrowded compartment 39. In the case of* B. parviflora, *the highest number of seedlings belonged to the H_1 (below 1') class (over 80% of the total) both before and after logging. An increase of about 16% was recorded in the number of this species in logged-over plot 6. However, most of the plots in the present study were found to be adequately stocked with* Rhizophora *seedlings.*

[1] District Forest Officer, Bentong, Pahang.

Key to authors' names: Srivastava P.B.L. and Abdullah Sani

INTRODUCTION

The Matang Mangrove Forest Reserve is situated on the West Coast of Peninsular Malaysia. The area of the Reserve is 101,134 acres which is about 37 per cent of the total mangrove forests in the country including Sarawak and Sabah. These forests are of considerable economic, environmental and social importance. Economically, the most important species are *Rhizophora apiculata* and *R. mucronata* although as many as 43 species have been reported from the mangrove swamp of the Peninsula (Watson, 1928). The mangrove wood is used for charcoal making, firewood, piling poles and fishing stakes. The bark also yields tannin. In Sabah and Sarawak, the wood is chipped and exported to Japan (Liew *et al.* 1977). The mangrove forests also have a far reaching impact on marine life, e.g. crabs, prawns, fishes, cockles, etc. which depend on the mangroves for their food supply and other needs (Mathias, 1974; Yusof, 1977).

Currently, the forests are being managed on a 'clear felling' system using a 30 year rotation (Mohd. Darus, 1969). The method of felling and transportation described by Corpuz (1972) also applies to the Matang Mangrove forest. The trees are felled by chainsaw, cut-up into billets, debarked and transported by small boats or by small rail-tracks. Before final felling, there are three mechanical thinning schedules viz; first thinning at the age of 15 years with a 4 ft. stick, second at the age of 19–20 years old crop with a 6 ft. stick and the third at the age of 25–26 years with a 7 ft. stick. Where there is a danger of the fern *(Achrostichium aureum)* invasion after clear felling, standards are retained. According to Noakes (1951, 1952), standards should be retained in two types of areas viz; the fern infested ones and deeply flooded areas. It has been observed (Noakes, 1955; Dixon, 1959; Abdul Manap and Srivastava, 1975) that clear felling results in two important changes, viz; (i) it encourages the regeneration and growth of *Bruguiera parviflora*. Large areas have been 'degraded' by the presence of *B. parviflora* in the new stands after felling (Mohd. Darus, 1969), (ii) a weed fern *Acrostichium aureum* generally appears on the drier sites which inhibits the growth and establishment of *Rhizophora* seedlings. This fern occurs in two forms, "piai lasa" which is comparatively small and tufted and "piai raya" which may reach a height of twelve feet or more and forms a continuous thicket. Areas that have been invaded by "piai raya" are generally considered to be useless for further production of firewood species. Repeated attempts to eradicate it have failed and it has been found uneconomical to artificially regenerate such areas.

Most of the information on the harmful effects of logging on the natural regeneration is so far based on the observations of the foresters associated with the management of these forests. No quantitative assessment has ever been attempted. According to Noakes (1955), whatever regeneration is present in a mature *Rhizophora* stand is destroyed at the time of final felling. Dixon (1959), on the other hand, was of the opinion that not much harm is caused to the seedling during logging operations and many of the partially damaged seedlings were capable of recovery by coppicing. In some of the inland forests, damage to the natural regeneration, has been reported to be as much as 40 – 45 per cent (Nicholson, 1958; Wyatt-Smith, 1962).

The present study was, therefore, undertaken to determine:-

i) proportion, distribution and size classes of *Rhizophora* and *Bruguiera parviflora* seedlings before and after final felling,

ii) the extent of regeneration destroyed by final felling, and

iii) the height class most affected by logging operations.

METHOD OF STUDY

In order to have reliable information on the natural regeneration in terms of distribution, stocking and composition of species in different size classes, representative sites were selected in typical *Rhizophora* type where the predominant species was *R. apiculata*. These sites, situated in Port Weld Range, were not prone to fern invasion after clear felling and belonged to Watson's (1928) inundation classes III and IV which are frequently inundated by medium high tides. The whole area is interspersed by many small streams which help in seed dispersal and accessibility for management.

Small motor boats can go deep into the forest at high tides. The soil is stiff mud with high clay fraction and moisture content. It forms the "Brown Mangrove Loam" with a high content of semi-decomposed organic matter and low content of sand in certain pockets (Noakes, 1951). The soil surface was found to be firm except along the banks and channels. However, walking through the stands was very difficult and time consuming because of numerous stilt roots (Plate 3) and streams along the path of the sampling lines.

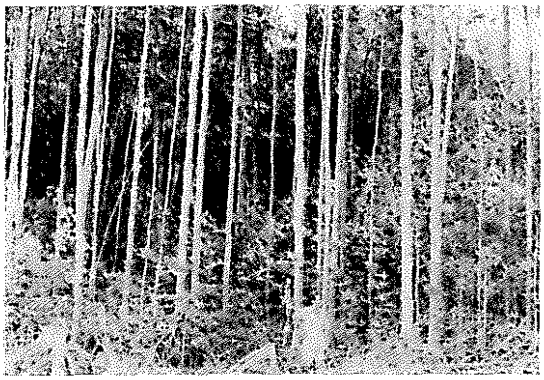


Plate 1. Crop ready for Final Felling, Compartment 39 B (Plot 3).

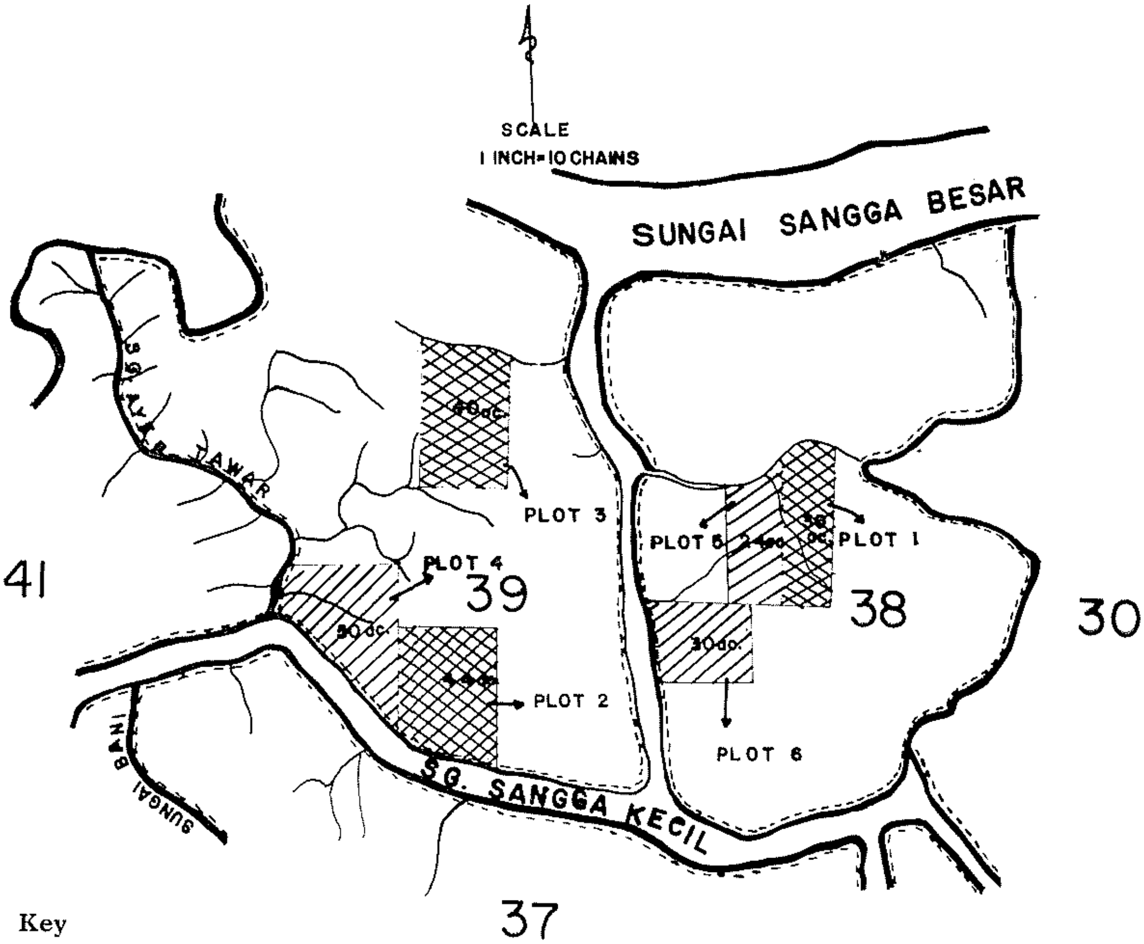
Plate 2. Seedling Crop before final Felling, Compartment 39 A (Plot 2).

Plate 3. The interwoven stilt roots, compartment 38 (Plot 1).

Plate 4. Area immediately after logging. Note the amount of slash, Compartment 39 (Plot 4).

In all, six sites were chosen (Fig. 1, and plates 1, 2, 3 and 4), of which three were ready for final felling and in the other three felling was completed during the last six months (Table 1). Although the same sites were not sampled at the two stages due to time constraints, the plots before and after felling were selected so as to be as homogenous as possible. An ocular reconnaissance survey was carried out. All possible factors which might have influenced the natural regeneration were taken into consideration. All the plots were chosen as near as possible in the two adjoining compartments (nos. 38 and 39) surrounded by *Rhizophora* dominated crop and same stream system (see the map). Since the time lag between felling and survey was small, it was logical to presume that the low number of seedlings in the residual (post-felled) stands would be most likely due to damage by logging.

The Linear Regeneration Sampling procedure (LRS 1) (Anon, 1975) was used in the present study. This method has been developed for the assessment of natural regeneration of inland Dipterocarp forests. However, the method was also used by Liew *et al.* (1977) in their study of natural regeneration in Sabah Mangrove Forests. Following the standard procedure, a base line was drawn along a convenient boundary, such as a channel or a compartment limit. Along the base line, sampling lines were laid out at equal intervals of 10 chains. Milliacre quadrats were laid out contiguous to each other on the right side of each sampling line. This yielded a one per cent sampling intensity. The seedlings encountered in the milliacre quadrats were recorded by species and numbers in three height classes, namely, H_0 (0 – 1′), H_1 (1′ – 5′) and H_5 (5′ – 10′). The survey was completed in October-November, 1976.



Key

#	Plots before final felling.
/ / / /	Plots after final felling.
– – – –	Compartment boundary.
═══	Rivers.

Fig. 1. Part of the Matang Mangrove Reserve showing the areas sampled.

TABLE 1

Area of sample sites

Stages	Site	Plot No.	Area (acres)	No. of milliacre quadrats
1. Before final felling	Compartment 38	1	30	300
	Compartment 39(A)	2	44	510
	Compartment 39(B)	3	40	540
	Total		114	1350
2. After final felling	Compartment 39	4	50	358
	Compartment 38(A)	5	24	180
	Compartment 38(B)	6	30	274
	Total		104	812

RESULTS AND DISCUSSION

(1) *Composition of seedling crops*

The data collected at 1 per cent sampling intensity were analysed to determine the composition and stocking density of the seedling crop in different plots before and after logging.

The most common species present in all the plots except plot 3 before and after felling were *Rhizophora* spp. (Table 2). *Rhizophora mucronata* Lam. was mostly concentrated along the banks where its large seedlings easily get a footing in the deep and soft mud. On the other hand, *R. apiculata* Bl. seedlings were dispersed all over the area. *Bruguiera parviflora* (Roxb). W. & A. ex Griff was the most impottant associate of *Rhizophora* species, both before and after felling. Other species, for example, *Bruguiera cylindrica* Bl., *B. gymnorhiza* (L.) Lam. were only sparsely present. Most of the discussion below will, therefore, be related to different aspects of *Rhizophora* spp. and *B. parviflora* seedlings.

(2) *Abundance of natural Regeneration*

All the three plots before felling were highly stocked (Table 2). *Rhizophora* species seedlings were most abundant comprising 68 per cent of the total stocking. *B. parviflora* seedlings accounted for 30 per cent and other species for the remaining two per cent. *Rhizophora* seedlings were more than two times as abundant as *B. parviflora* (R/B ratio = 2.26).

There was a wide variation in the number of seedlings in the pre-felled plots. Exceptionally, a higher number of seedlings was recorded in plot 2 (14014 per acre) and the lowest (3578 per acre) in plot 3. The magnitude of variation was even higher in different plots in the case of *B. parviflora*. There were as many as 9033 seedlings per acre of this species in plot 3 compared to only 168 seedlings per acre in plot 2. In fact, in plot 3, seedlings of *B. parviflora* out-numbered those of *Rhizophora* by about two and a half times. Considering the total number of seedlings of the two species together, plots 2 and 3 had more than two times the density (2.5 and 2.2 respectively) of plot 1.

At this stage (before felling), there was also considerable variation in different height classes of the two species in various plots (Table 3). In all the plots, the highest number of seedlings of *Rhizophora* species was recorded in H_1 class and the lowest in H_5, the number varying between 2710 and 10234 seedlings per acre of the former and 70 to 466 of the latter. On an average, H_1 class accounted for 72 per cent, H_0 25 per cent and H_5 for only 3 per cent of *Rhizophora* seedlings. The situation was slightly different in the case of *B. parviflora*. Instead of H_1 class, H_0 had the highest number of seedlings in all the three plots, but again H_5 class was most poorly represented. On an average, H_0 class accounted for 85 per cent while H_1 and H_5 contributed to only nine and

TABLE 2

Species composition and stocking of seedlings in different plots

(i) Before final felling

Sites	Plot No.	Number of Seedling/Acre			
		Rhizophora spp.	*B. parviflora*	*B. gymnorhiza*	*B. cylindrica*
Compartment 38	1	4943	776	20	–
Compartment 39(A)	2	14014	168	127	84
Compartment 39(B)	3	3578	9033	213	43
Average/Acre		7512	3326	120	42

(ii) After final felling

Sites	Plot No.	Number of Seedling/Acre			
		Rhizophora spp.	*B. parviflora*	*B. gymnorhiza*	*B. cylindrica*
Compartment 39	4	1814	550	12	2
Compartment 38(A)	5	4483	4	8	50
Compartment 38(B)	6	4120	900	33	–
Average/Acre		3472	485	18	17

TABLE 3

Number of seedlings per acre in different height classes

(i) Before final felling

Sites	Plot No.	*Rhizophora* spp.			*B. parviflora*			Total			Grand Total
		H_0	H_1	H_5	H_0	H_1	H_5	H_0	H_1	H_5	
Compartment 38	1	2130	2710	103	530	203	43	2660	2913	146	5719
Compartment 39(A)	2	3314	10234	466	102	18	48	3416	10252	514	14182
Compartment 39(B)	3	93	3415	70	7825	670	538	7918	4085	608	12611
Average/Acre		1846	5453	213	2819	297	209	4665	5750	422	10847
	%	25	72	3	85	9	6	43	53	4	

(ii) After final felling

Sites	Plot No.	*Rhizophora* spp.			*B. parviflora*			Total			Grand Total
		H_0	H_1	H_5	H_0	H_1	H_5	H_0	H_1	H_5	
Compartment 39	4	388	1364	112	424	94	32	762	1458	144	2364
Compartment 38(A)	5	2679	1771	33	4	–	–	2683	1771	33	4487
Compartment 38(B)	6	1550	2530	40	750	133	17	2300	2663	57	5020
Average/Acre		1522	1888	62	393	76	16	1915	1964	78	3957
	%	44	54	2	81	16	3	48	50	2	

six per cent of the crop of this species respectively. This indicates that the recruitment in the form of seedlings starts appearing only after the slash resulting from III thinning has decomposed, that is, only during the two to three years before final felling.

After logging, marked differences were observed in stocking intensity though *Rhizophora* seedlings were still the most abundant comprising 87 per cent of the crop. *B. parviflora* accounted for 12 per cent. The former were about seven times more abundant than the latter. However, the magnitude of variation in the abundance of variation in different plots was reduced, the number ranging between 1841 seedlings per acre in plot 4 and 4120 seedlings per acre in plot 6. A similar trend was observed in the case of *B. parviflora*. Considering the total number of seedlings of the two species together, plot 6 had the highest density (5020 seedlings per acre) and plot 4, the lowest (2364 seedlings per acre).

As regards the number of seedlings in different height classes the situation was somewhat the same, that is, H_1 was the dominant height class of *Rhizophora* seedlings though its percentage contribution was decreased (54 per cent) compared to pre-felled stage (72 per cent). On the other hand, H_0 class accounted for 44 per cent of the total number of seedlings of this species. H_5 class still had the lowest density of *Rhizophora* seedlings. Similarly in the case of *B. parviflora,* H_0 still had the highest number of seedlings accounting for 81 per cent, H_1 16 per cent and H_5 for only 3 per cent.

(3) *Damage due to logging*

In compartment 38, there was little difference in the stocking density of *Rhizophora* seedlings (c.v. = 9 per cent and s.e. = 5 per cent) in plot 1 (before felling) and plots 5 and 6 (after felling). The reverse was, however, true for *B. parviflora* seedlings (c.v. = 87 per cent and s.e. = 5 per cent) in the same compartment. Further, there was an increase of about 16 per cent in the number of *B. parviflora* seedlings in plot 6 (post felled) compared to plot 1 (pre-felled). On the other hand, in compartment 39, a considerable reduction in the number of seedlings of *Rhizophora* spp. was recorded, in the adjoining plot 4 (post-felled) compared to plot 2 (pre-felled). If it is assumed that the stocking was more or less the same in this part of the compartment (plot 4); felling caused high damage to the regeneration of *Rhizo-*

phora and a small increase in the number of *B. parviflora* seedlings. Plot 3 appears to be exceptional in that though it formed a part of the compartment 39, it was situated away from the other plots and there were more than twice the number of *B. parviflora* seedlings than those of *Rhizophora* even prior to clear felling.

The analysis of the data indicates that there can be a large variation in regeneration status even in different parts of the same compartment. Such a variation was also recorded by Liew *et al.* (1977) in Sabah mangrove forests. This is probably due to the part played by tides in the dispersal of seedlings before or after felling in these forests and hence the nearness of different parts of the compartment to the channels, streams and rivers.

Within the limits of variation, irrespective of compartments, there was a decrease in stocking density after felling. The number of *Rhizophora* seedlings decreased by nearly half of its value in pre-felled plots. The decrease was even greater, by nearly seven times in *B. parviflora.* The number of the two species taken together decreased by more than two times.

As far as the effect of felling on different height classes is concerned, it may be noticed that in compartment 38, logging does not appear to have a pronounced deleterious effect on H_0 and H_1 height classes of *Rhizophora* seedlings, the average number of seedlings being 2114 and 2150 per acre respectively in plots 5 and 6 (post-felled) compared to 2130 and 2710 seedlings per acre in plot 1 (pre-felled). However, there was a pronounced reduction in the number of seedlings of this species in H_5 height class after felling. As against 103 seedlings per acre in plot 1, there were only 33 and 40 seedlings per acre in plots 5 and 6 respectively. In the case of *B. parviflora* the number of seedlings was markedly reduced after logging in all the height classes except H_0 in the former where its number rose to one and a half times that in the pre-felled situation. In compartment 39, on the other hand, there was a very high reduction in the number of *Rhizophora* seedlings particularly in the lower two height classes as a result of logging (plot 4 verses plot 2). This is mainly due to the fact that this part of the compartment was rather overcrowded with *Rhizophora* seedlings before felling. However, *B. parviflora* seedlings registered a definite increase on the same site after logging. Irrespective of the compartment, felling resulted in the decrease of the number of seedlings in all the height classes of the two species, though the effect is very pronounced on H_1 and H_5 height classes of *Rhizophora* species and H_0 and H_5 height classes of *B. parviflora* (Table 3). While the damage to *B. parviflora* is mostly intentional because the contractors are instructed to destroy this species at the time of felling, the reduction of *Rhizophora* seedlings was certainly due to logging operations. From the above, it would appear that the high magnitude of damage to *Rhizophora* regeneration is confined only to overcrowded compartments.

(4) *Adequacy of Natural Regeneration*

In any forest stand, a plot must have a minimum number of seedlings to start with if it is to develop into a mature crop at the end of rotation to give the anticipated yield. For the inland forests, the Linear Regeneration Sampling Procedure (Anon, 1975) recommends a minimum acceptable stocking of 30 per cent milliacre plots (or 300 seedlings per acre), with a 12 per cent allowance for mortality. It, however, does not indicate the number of seedlings of a particular height class that should be present in each stocked quadrat. Srivastava (1973), suggested that if a milliacre plot had at least one established seedling (i.e. between 5′ – 10′) or four unestablished seedlings (i.e. recruitment between 0′ – 5′) of *Shorea robusta,* it might be considered a fully stocked quadrat. It was presumed that at least one out of four unestablished seedlings would survive to develop into a mature tree.

There are no available data yet pertaining to mangrove forests which recommend stocking for regeneration considered to be adequate. A figure of 300 seedlings per acre would be a very low number and would not reflect the situation generally occurring in *Rhizophora* dominated mangrove forests. In these forests, there has to be more than one seedling per milliacre quadrat to ensure enough stems at the time of final felling apart from the stems extracted during the three thinnings, obviously because of the marked differences in the composition of the lowland forests and *Rhizophora* stands. The typical inland forests are multitier and extremely heterogenous with a large number of tree species in many height and diameter classes. On the other hand, mangrove forests in this region are single species dominated and are more uniform in growth. The adequacy of regeneration has, therefore, to be estimated on the basis of the expected or potential number of stems per unit area at the time of final felling as well as after every thinning. For this an assumption is also needed in respect of mortality of seedlings during the whole rotation period.

However, the yield in these forests is not estimated on the basis of number of stems per unit area at the time of final felling or after every thinning. It is calculated on the weight basis which varies from 1000 – 1500 piculs per acre (Nik Anwar Nik Salleh – personal communication). Mohd. Darus (1969), however, estimated that there would be about 500 stems per acre at the time of final felling, out of which about 400 belong to *Rhizophora* spp. and the rest to other species, mainly *B. parviflora*.

The III thinning, wherein the stems are left at 7′ × 7′ spacing, yields 889 stems per acre. A density of 500 stems per acre can, therefore, be expected, if there is no large scale mortality between the III thinning and final felling. The II thinning at a spacing of 6′ × 6′ gives a density of 1210 stems per acre. It can safely be assumed that any mortality between II and III thinning will be covered so as to yield 889 stems after III thinning. Similarly the number of stems after I thinning at a spacing of 4′ × 4′ would be 2722 stems per acre. Currently planting of *R. apiculata* is carried out at 4′ × 4′ spacing in the poorly regenerated and blank areas, thus yielding a density of 2722 equally spaced seedlings per acre. However, there is an increase in the number of seedlings after planting due to tidal action and the excess number is removed at the time of I thinning. It may be seen that a mortality of up to 50 per cent due to any natural cause between the I and II thinning will be covered by the difference in the number of stems per unit area after I (2722 stems per acre) and II (1210 stems per acre) thinnings.

Since there are no available data to show the incidence of recruitment and mortality between the final felling and I thinning of the next rotation, it is assumed for the purpose of the present study that the mortality is balanced by the recruitment during this period. This would indicate that a density of 2722 seedlings per acre may be considered adequate after logging in order to give 889 or a minimum of 500 stems per acre at the time of final felling. The former figure, i.e. 2722 stems per acre, is equivalent to 2.72 seedlings per milliacre plot. In other words, there should be at least three seedlings per milliacre plot left after final felling so as to develop into a stand of desired density for the next rotation.

It is evident from the Table 3(ii) that though there appears to be appreciable damage due to logging particularly in the overcrowded stands, enough seedlings remain to produce a fully stocked stand at the time of first thinning and thereafter. In the present study, only plot 4 was found to be slightly understocked. It would be interesting to find out the rate of recruitment and mortality in the seedling crop after final felling till the stage of first thinning by sampling at a minimum acceptable interval.

CONCLUSIONS

On the basis of the present study, the following conclusions can be derived:

(i) All the plots both before and after final felling are highly stocked particularly with *Rhizophora* spp. seedlings.

(ii) *Rhizophora* spp. seedlings are more abundant than *B. parviflora* both in plots before and after logging.

(iii) There is a considerable variation in the number of seedlings in different height classes in various plots both in pre-felled as well as post-felled areas, even in the same compartment.

(iv) The effect of logging appears to be variable. It is highly damaging to the seedlings in the overcrowded stands where all height classes of *Rhizophora* species are affected. In the thinly populated stands more damage is caused to higher height class of seedling of *Rhizophora* species.

(v) A definite increase was seen in the stocking of *B. parviflora* after logging in compartment 39 particularly in the lower height classes.

(vi) In order that a stand be taken as fully stocked, each milliacre plot should carry at least three seedlings of the preferred species, i.e., the *Rhizophora* species. In the plots sampled in the present study, most of the area was found to be covered with three seedlings per milliacre plot before and after final felling.

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